The Fire Fighting Foam Fight: The Controversy over Toxic Fire Retardants

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LeeYung W. Chang

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

S. Travis Elliott, Department of Engineering and Society

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Introduction

Aqueous film-forming foams, commonly abbreviated to "A-triple-F" or AFFF, are a series of firefighting compounds particularly relevant to liquid fuel and crash firefighting applications (Caban-Martinez et al., 2019). These materials were originally developed by the U.S. Navy in the 1960s to improve firefighter safety and meet stringent military-specified guidelines – in order to meet these objectives per- and polyfluoroalkyl substances (PFAS) are frequently used (Caban-Martinez et al., 2019). Unfortunately, these same substances generate significant environmental and health risks, being connected to increased incidence of certain cancers, obesity, and immune suppression, among other health hazards (Caban-Martinez et al., 2019; Clean Water Action, 2020; Henderson et al., 2020). With increased awareness and detection of PFAS-related hazards, several instances of legislative action, ongoing and passed, have set limitations on PFAS use (Henderson et al., 2020; Reisch, 2019). Despite broad consensus on the harmful effects of PFAS and the need to address the problem, AFF foams with PFAS content continue to present a unique dilemma – in their use as fire retardants, runoff and consequent PFAS entry into the ecosystem is inevitable, yet at the same time PFAS inclusion is specifically correlated with improved firefighting effectiveness – critical in the sort of emergency situations where AFFF often finds its use (Back & Farley, 2020; Fire Fighting Foam Coalition, 2019). This paper will examine the issues at hand and potential solutions through the social construction of technology (SCOT) and ethical frameworks.

STS frameworks

The social construction of technology (SCOT) is a theoretical approach to science and technology studies (STS), originating in Pinch and Bijker's 1987 paper discussing a need to

address a perceived gap between sociological studies of science and of technology (Klein & Kleinman, 2002; Pinch & Bijker, 1984). Four interconnected concepts make up the original SCOT framework – interpretive flexibility, the relevant social group, closure & stabilization, and wider context (Klein & Kleinman, 2002). Interpretive flexibility, adopted from the Empirical Program of Relativism (EPOR) developed for the sociology of scientific knowledge, is used in SCOT to show how technologies are shaped by the social groups that they affect, and those groups' perceptions of those technologies (Klein & Kleinman, 2002; Pinch & Bijker, 1984). These relevant social groups are the second component of SCOT, the agents by whom technologies are shaped – they are sorted by the relation to a given technology; thus "all members of a social group share the same set of meanings, attached to a specific [technological] artifact" (Klein & Kleinman, 2002; Pinch & Bijker, 1984). Closure and stabilization is used to define a point at which conflicts between groups with different interpretations are resolved and some "final form" of the technological artifact is reached (Klein & Kleinman, 2002).

The final element, wider context, is fairly self-descriptive; while in that sense it is simple, in (ironically) a wider context it is where the majority of critiques of SCOT have focused (Klein & Kleinman, 2002). Within the SCOT framework relevant social groups are neat, defined, and equitable; contextually, differences in the balance of power, potential for inter-/intra- group conflict without closure, and difficulty in clearly defining groups present major challenges (Klein & Kleinman, 2002). As a result of these critiques a fifth concept, the technological frame (which Klein suggests is better understood when read as a "frame with respect to technology"), establishes the idea of a frame through which members of relevant social groups view a technology, thus defining those relevant social groups (Klein & Kleinman, 2002).

The challenges of SCOT can be broadly lumped into those of method and explanation (Klein & Kleinman, 2002). Method describes the question of capturing the wider context and making sure that all relevant social groups are accounted for and fairly represented – the standard approach, a "snowball," wherein initial actor-level identifications of social groups are "rolled up" until clear relevant social groups are established, risks both distorting social groups based on the initial actors identified and missing relevant social groups altogether, if actors within them are missed (Klein & Kleinman, 2002). The second challenge Klein identifies is that of explanation – SCOT , while able to identify successful social groups and their technological artifacts, may not be able to explain the factors leading to a given success – similarly, the concept of closure and stabilization has its basis in declaratory statements of when a particular artifact has reached its "final form" rather than *why* this is the case (Klein & Kleinman, 2002). In this study, while not a perfect analogue, several elements of wider context will be used as an analogue for potentially missed relevant social groups; groups not directly mentioned will be have the effects of their interpretive flexibility approximated as an element of context.

Beyond the SCOT framework, the moral complexity of this case makes it a strong candidate for additional analysis through ethical frameworks. Consequential and deontological ethical frameworks stand in opposition to each other. The former assesses the ethics of a decision on outcome - whether actual, foreseen, or otherwise is dependent on the particular form of consequentialism; the latter assesses ethics on the means by which a decision is made – here the variation is a matter of what judgement criteria, what moral norms, are used to assess the actual decision (Alexander & Moore, 2021; Sinnott-Armstrong, 2021). Virtue ethics, meanwhile, assesses decisions based on whether they embody a certain "moral character" – this is given as

some blend of virtue and practical wisdom; something which might be described as approximately an intuition to '"do the right thing" (Hursthouse & Pettigrove, 2018).

Framework-Topic Link

In a SCOT context, the technological artifact is fire-fighting foam, with interpretive flexibility being chiefly divided along lines of pure firefighting effectiveness as opposed to mitigation of risks to health and the environment, and the effects these foci have had on current firefighting foam formulations. With the binary nature of the question (i.e. whether PFAS should be included in firefighting foam) there are two broad "sides" taken – the most prominent groups opposing PFAS use are environmental groups, public citizens' groups, policy groups, and utilities; the primary groups in favor of PFAS use are the military elements which use AFFF and the manufacturers responsible for its creation (Fire Fighting Foam Coalition, 2019; Hughes et al., 2020; Panikkar et al., 2019; PFAS Central, n.d.; Vergun, 2020). While closure, as discussed previously, has yet to be reached, there are steps that have been taken within relevant social groups to reduce conflict and begin moving toward closure and stability, and the complex nature of the case ensures a need for careful consideration of the context.

There is a significant imbalance in power; as much decision-making power sits with the military. SCOT is able, in a limited capacity, to address this, using structural factors (Klein & Kleinman, 2002). With the balance of power being what it is here, however, the use of an ethical framework that is centered around potential decisions the pentagon can make will add valuable insight into potential motivations and actions.

Historical Context

While this paper focuses specifically on PFAS in AFFF, it is important to have some historical context for both the wider use of PFAS and the specific history of AFFF.

One of the defining moments in the history of US Navy damage control operations was the 1967 fire aboard the carrier *USS Forrestal* (CVA 59) (Stewart, 2004). While carrying out operations off the coast of Vietnam, with aircraft fully armed and about to take off for an attack run, a misfired rocket went through a light attack aircraft, tearing open its fuel tanks and igniting a conflagration which would last more than 24 hours, claim 134 lives and 161 injuries, and cost $72 million and two years of repair (SERDP/ESTCP, 2019; Stewart, 2004). In response to the fire, the US Navy implemented wide-ranging changes to both doctrinal and material aspects of firefighting operations (SERDP/ESTCP, 2019; Stewart, 2004). One such element was the development of AFFF, which would enter service only a few years after fire aboard *Forrestal* and a similar, though better contained, fire aboard *Enterprise* some 18 months later (SERDP/ESTCP, 2019; Stewart, 2004). Stewart, in discussing the factors enabling significant and rapid change in a large and bureaucratic organization, points to the massive loss of life as a galvanizing factor – it is possible that the development of AFFF in such a context would contribute to reluctance to switch to a potentially less effective firefighting foam (Stewart, 2004).

Having discussed the broader context of AFFF, it is worth discussing some of the ways in which PFAS use has been shaped in other settings. The unique properties of these compounds have led to their prominent use in industrial and consumer products, which has in turn resulted in a great deal of exposure to these materials in the greater public (Richter et al., 2021; Wickham & Shriver, 2021). Recent awareness of toxicity as well as difficulty of contamination treatment, as discussed previously, have begun to spur legislative action to restrict their use, including in firefighting foams (Clean Water Action, 2020; Henderson et al., 2020; Reisch, 2019). This relatively recent development of regulatory action has been controversial due to apparently suppressed knowledge within the industry of the toxicity of PFAS products and byproducts, with

knowledge of potential risks uncovered in litigation but otherwise shielded by trade secrecy for potentially decades (Richter et al., 2021; Wickham & Shriver, 2021). Between the scarcity of data and complexity of contamination, chemical producers been accused of working to "muddy the waters" on the potential hazards of chemicals and further taking advantage of a "coerced ignorance," where state agencies, limited in their ability to process and provide information, may resort to self-censorship, fearing local economic impact of an informed public (Wickham & Shriver, 2021). These factors, which benefit segments of the chemical industry which produce PFAS for a wide range of applications, have in the past forestalled discussion of the hazards of AFFF. Potential need for AFFF treatment has been discussed since at least 1974, when an assessment of biodegradability was conducted by the USAF (Kroop & Martin, 1973).

Conversely, local-level groups such as Merrimack Citizens for Clean Water (MCFCW) have organized to highlight local PFAS contamination and hazards (Panikkar et al., 2019). Here the PFAS source was an upstream chemical plant, spurring a community project which saw 600-odd people answering a citizen-initiated survey on demographics, exposure, and health conditions, and brought awareness to health concerns among groups with more exposure to PFAS (Panikkar et al., 2019). Similarly at a "downstream" level, publications in the American Water Works Association (AWWA) Journal emphasize a proactive approach to alerting consumers to potential PFAS risks in water supply, allowing initial risk mitigation by consumers and establishing trust in case future measures are required (Henderson et al., 2020). A panel discussion published in the same journal featuring water utility leaders indicates rising awareness of the PFAS threat, with several panel heads expressing awareness of the issue and mentioning proactive testing measures, again with a focus on keeping communities involved and building trust and understanding (Hughes et al., 2020).

Analysis

The relevant social group with the greatest power here is the US Department of Defense (DoD) – it is the developer and chief user of AFFF, and as a result has the most agency – by way of military specification, the DoD outlines a very specific set of requirements and explicitly frames the technology – here it is framed per set performance metrics which must be met (Caban-Martinez et al., 2019; MIL-F-24385F). The DoD, then, interprets AFFF primarily as a firefighting technology and works to optimize its performance as such – in various press releases and studies of alternatives, a need to meet stringent performance criteria and an inability to meet those criteria with alternatives are given as reasoning for continued AFFF use (Office of the Inspector General - U.S. Department of Defense, 2021; SERDP/ESTCP, 2019; Vergun, 2020). This does not mean that the ecological effects are ignored completely – updated directives have restricted use of AFFF in non-emergency situations and steps towards cleaning, phasing out, and otherwise mitigating PFAS exposure due to AFFF are, as of writing, actively being researched and implemented (Environmental Working Group, n.d.; Office of the Inspector General - U.S. Department of Defense, 2021; SERDP/ESTCP, 2019; Vergun, 2020). One noteworthy element of framing is the current specification's demand for a film-forming foam, which at present necessitates PFAS use; by dictating a technical mechanism this technology and the issue it is designed to solve are filtered through a particular frame, though the same report explicitly acknowledges this as a limitation, and an area of potential improvement (SERDP/ESTCP, 2019).

While the active attempts to find an alternative continue to see society shape this technology, the power which the DoD wields has allowed a sort of "pseudo-closure" – the conflict over interpretations of the technology between relevant interest groups is very much real, and the technology is clearly not in a final state, as indicated by the search for alternatives, yet

the technological artifact of AFFF has held the same stable form for over five decades now. One might make the argument that this meets the definition of rhetorical closure insofar as one group has concluded that every possible step is being taken, but not only does the problem remain unsolved, but the relevant social groups see the problem as unsolved – to some extent, this reflects Klein and Kleinman's discussion of power relations with respect to closure (Klein & Kleinman, 2002).

Differences in technological frames shape the arguments made by environment-oriented groups: these groups, speaking broadly, tend to interpret AFFF as a potential health and environmental risk above its status as a firefighting element (Clean Water Action, 2020; Environmental Working Group, n.d.; Panikkar et al., 2019). The collective of environmental advocacy groups forms a relevant social group – these groups lack the *de jure* power available to the DoD, but are able to influence public opinion and as such exercise a certain degree of power – the agents that form this social group include groups like the Green Science Institute, which through its PFAS Central arm provide what they deem "current and curated information" about PFAS risks, including legislative action and peer-reviewed articles, evidence which spreads public awareness and which environmental groups such as Clean Water Action use to lobby for legislative change to phase out PFAS use (Clean Water Action, 2020; Lindeman, 2017; PFAS Central, n.d.). Another agent in this group, the Environmental Working Group, has listed a timeline of DoD reports on the risks of AFFF, claiming that risks have been known but not acted on for "decades" (Environmental Working Group, n.d.).

From a SCOT perspective, these might reflect interpretive flexibility – calls to action are made, based on how a relevant social group views a technological artifact; and as part of this call to action the technological frame that this social group uses is propagated, resulting in an

increase in the size and social strength of relevant social groups with shared interpretations of this technology, allowing them to in turn further influence the growth of the artifact, here referring to AFFF – an argument could be made that this action has spurred limitations on AFFF use and the current search for alternatives (Klein & Kleinman, 2002; Pinch & Bijker, 1984). If one makes this argument, another argument that can follow is that in this case societal input has occurred to a certain extent without respect to expected structural and power differences like those mentioned by Klein – while the "pseudo-closure" discussed above remains in effect, with AFFF use continuing, the drastic reduction in use, acknowledgement of health risks, and search for an alternative show a shift in consensus for what the final form of AFFF should look like, to be more in line with that advocated by these groups (Klein & Kleinman, 2002; Pinch & Bijker, 1984). An alternative reading would be that addition to the "soft" element of public pressure, these groups are able to bring in various regulatory and legislative government agencies as relevant interest groups with significant power, and whose interpretations of AFFF use are similar – this would coincide with the legislative changes that have seen PFAS and AFFF use reduced, and at many civilian airports eliminated outright (Henderson et al., 2020; Reisch, 2019).

A third (arguably fourth) relevant social group which merits some discussion is the collective of firefighting foam manufacturers – to better reflect their interests many of the manufacturers of firefighting foam are formed in a trade association known as the Fire Fighting Foam Coalition (Fire Fighting Foam Coalition, 2019). For members of this group, AFFF might be framed as a strong, profitable product first and foremost, and thus one worth protecting – as noted above, manufacturers of PFAS have previously been found to hide or downplay the potential toxicity of their product, in order to encourage increased adoption, and thus a larger market (Richter et al., 2021). With that said, trying to place "manufacturers" under a single

relevant social group is an oversimplification. Many of the manufacturers which make up the Coalition also manufacture fluorine-free firefighting foams (FFF), which are major alternatives – in fact 3M, formerly the largest AFFF manufacturer, phased out certain PFAS after a whistleblowing scandal as early as 2000 (Fire Fighting Foam Coalition, 2019; Richter et al., 2021). The argument made in press releases by the Fire Fighting Foam Coalition, such as the cited paper, a response to an expert panel convened by the International Pollutants Elimination Network (IPEN), has generally been in line with that made by the DoD, i.e., that alternatives do not match AFFF in performance, an assertion contradicting the IPEN article and somewhat supported in a separate evaluation (Back & Farley, 2020; Fire Fighting Foam Coalition, 2019; IPEN, 2018). Broadly speaking, manufacturers have historically attempted to downplay PFAS hazards expand utilization, but at this point in time even here the focus is on remediation; the toxic nature of AFFF is acknowledged but regarded as an unavoidable element of the need for a film-foaming surfactant to put out fire (Fire Fighting Foam Coalition, 2019).

Analysis by Ethical Frameworks

As discussed previously, the DoD ultimately has agency over the decision-making process; given this fact, I would like to examine the actions of the DoD, potential and otherwise, through ethical frameworks.

Through a consequentialist lens, the question can be distilled thusly: to do good, is it better to maximize your ability to save service members and materiel from harm or minimize the harm done to the surrounding population? Adding to this dimension is uncertainty – while harm from runoff chemicals can be quantified to some degree by ecologists, “lives saved by a more effective firefighting foam” is a very complex quantity to determine. How much does a “slightly improved” firefighting material truly generate benefit? How does this change between a single

plane, completely evacuated, burning on a barren stretch of runway, as opposed to armed and close-packed aircraft about to take off on a mission? Likewise, how can harm to persons be quantified and compared? Is a burn sustained from a fire that went 10% further than it otherwise would have a "better" or "worse" outcome than an increased risk of cancer for a small town?

In a deontological sense, an overarching rule to define the purpose of the military might be to defend those whom it serves. Even here it's possible to dance with semantics: is it better to defend by maximizing readiness and damage control, or is it better to defend the well-being of civilians by not directly affecting their health?

Virtue ethics is a third, different beast – for a complex issue with so many moving parts, as seen in the section regarding consequentialism, I think the ultimate question becomes a matter of truth – as seen in SCOT analysis, frameworks and interpretations are not inherently deceptive, yet the conclusions one might reach vary vastly depending on which framework one chooses to view AFFF through.

I consider the answer to be right in the name of AFFF – while this paper has focused on the social aspect, trying to completely separate the technical from technology is a fool's errand, especially here, where the technical is shaping responses to technology. Ultimately, that aqueous **film-forming** foam is too large a difference to bridge with present technology – I think that the film, which is what the PFAS chemicals present assist in forming, so significantly enhances firefighting ability that a switch to an alternate technology at present would be an unacceptable increase in risk (Back & Farley, 2020). The communities and the people that have been affected are however owed compensation – I believe that remediation and treatment are the correct thing to do, and I believe that alternatives are a necessary avenue to pursue, but I do not consider a sacrifice to ship safety until an improved formulation is found acceptable. Very reasonable

counterarguments can be made that the change in firefighting effectiveness is relatively small, or perhaps even that the metrics being measured do not adequately capture FFF performance while these are good arguments, and may even apply to other militaries with different armed forces compositions, it is my belief that the best possible firefighting capability – particularly in aircraft carriers, in which many volatile materials sit in close proximity – is critical. Another, certainly credible, concern is that in layers of bureaucracy will prove obstacles to remediation and finding an alternative alike – these are reasonable concerns, especially in light of the health hazards; I do not dispute that they are hazards, but I believe they should be addressed rather than solely avoided. In line with the previous statement, I believe there is a moral imperative to address remediation more strongly, especially given the significant challenges and the nascent nature of the field – this particular element is one that could be discussed not only in the context of AFFF, but in the wider scope of PFAS toxicity concerns (Ross et al., 2018).

Conclusion

In this thesis the continued usage of Aqueous Fire Fighting Foam (AFFF) was analyzed through Social Construction of Technology (SCOT) and ethical frameworks. In the SCOT framework, the key original elements, as proposed by Klein & Kleinman, are interpretive flexibility, the relevant social group, closure & stabilization, and wider context; to this technological frame is suggested by Pinch and Bijker (Klein & Kleinman, 2002; Pinch & Bijker, 1984). The relevant social groups discussed were the Department of Defense, environmental advocacy groups, and firefighting foam manufacturers, with interpretations of AFFF concisely summarized as firefighting material, ecological hazard, and profitable product. The odd state of stability but not closure, which I dubbed a “pseudo-closure”, was discussed, along with its accompanying power imbalances; likewise, the ability of ecological groups to leverage public

pressure and spur change despite the massive gap in de jure power was discussed. Finally, a brief overview was given of potential ethical considerations, and the difficult tradeoffs therein, from the perspective of the DoD, which was the relevant social group with the greatest amount of agency.

I believe the current tradeoffs taken reflect the optimal solution – while AFFF remains in use, it is very limited, and replacements which minimize ecological harm are actively researched. While remediation is a work in progress, I believe that more work ought to be done there to mitigate the dangers of PFAS from all sources, not just AFFF. In researching AFFF as a technical artifact, it is fascinating to see how societal factors have shifted the technical frames of all the parties involved – no longer is the potential harm a question of major contention; rather contention today lies with determining what the best way to mitigate that harm is.

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